

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

METHODS AND DEVICES FOR REDUCING STRESS CONCENTRATION WHEN
SUPPORTING A BODY

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1 TITLE OF INVENTION

2 Methods and Devices for Reducing Stress Concentration
3 when Supporting a Body

4

5 CROSS REFERENCE TO RELATED APPLICATIONS

6 Not applicable

7

8 STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR
9 DEVELOPMENT

10 Not applicable

11

12 REFERENCE TO A MICROFICHE APPENDIX

13 Not applicable

14

15 BACKGROUND

16 A person who is elderly or has some enervation and is
17 confined to bed for an extended period, will have a
18 propensity to develop tissue trauma sores (ischemic ulcers,
19 decubitus ulcers or bedsores). Typically these sores appear
20 over bony prominences where forces arising from the weight of
21 the body are concentrated and the lack of movement leads
22 to tissue destruction. (Those with normal sensation and
23 mobility become "uncomfortable" and move to a different
24 position while those under anesthetics can't move) To avoid
25 such sores, some form of tissue pressure/shear interface
26 should be provided to reduce these forces to a value that the
27 tissue can tolerate. These tissue trauma forces may be

1 adjusted in a number of ways; by "putting the load where the
2 body can tolerate it", by attempting to control interface
3 forces across the patient body support surface, or by moving
4 the patient periodically before tissue reaches an irreversible
5 "death" situation.

6

7 DESCRIPTION OF PRIOR ART

8 In recent years, inventors have approached this problem
9 of tissue breakdown prevention using two basic approaches for
10 body support, fluidic substance or polymeric foam. Each of
11 these methods encompasses many variations that have met with
12 differing degrees of success. In most instances cross-
13 contamination or dust mite prevention has not been considered
14 as part of a performance requirement until after-the-fact

15 1. Fluidic support

16 Water/Air. Making use of a shaped structure and air
17 bladders was proposed by Weinstein et al in US Patent
18 3,456,270 wherein water was the supporting medium and a
19 lifting inflatable bladder interface was used for raising
20 patient for transfer etc.

21 Whitney in US Patent 3,802,004 changed a patient immersion
22 depth through unique bladder arrangements inflated by air,
23 without changing medium volume.

24 Hagopian in US Patents 5,072,468 and 5,068,935
25 describes a special bed frame for ease of manufacture and
26 the use of water as the base medium with an air bladder on
27 its upper surface to lower or raise the patient, as in

1 Reswick (later), with the added ability to provide an
2 inflated wedge for postural trunk control of the patient.
3 These approaches also were an attempt to reduce "hammocking"
4 over bony prominences that tends to negate the efficacy of
5 the support medium. It should be noted that the water bed of
6 today is comprised of water, a supporting envelope to
7 "hammock" a person so that they do not sink into the bed and
8 appropriate baffling or channeling for stability of the
9 water.

10 Air. There are a number of ways in which air has been
11 compressed, blown or applied to support a patient. Hart in
12 1926 in U.S. Patent # 1,772,310, described a technique of
13 alternating the fluidic support points on the body by
14 controlling the time each support point was to be activated,
15 while limiting interface pressure to an acceptable value.
16 Hart also introduced a method of patient turning in this same
17 patent.

18 Whitney, in US Patent 3,148,391 used a modified method
19 of support that was compact and introduced temperature
20 control of interface as well as the alternating method of
21 support. Ford in US Patent 4,711,275 opted to inflate and
22 deflate arrays of air cells through independent air
23 compressors to create an alternating pressure support system.
24 Krouskop in US Patent 4,989,283 opted to control height of
25 the supporting bladders in his approach to body support by
26 measuring any changes in cell configuration through a
27 microprocessor using its input from internal bladder sensors.

1 to control appropriate valving to pressure sources or
2 exhausts to maintain each bladder at some referenced height.
3 Others used lateral support tube shaping (Talley of the UK)
4 while others included an air loss to circumvent needle
5 puncturing problems (3M) with appropriate control mechanisms.

6 Air, as a fluidic support has been proposed in many
7 forms for various purposes of body positioning. A surgical
8 table is the subject of Canadian Patent 1035000 by Carrier
9 where individual bladders of air are positioned to keep the
10 bony prominences clear of the table, while providing a fairly
11 stable support as each bladder is independently inflated to a
12 desired pressure. All are then covered by a forgiving cover.

13 Air cushion machines are quite effective in supporting a
14 large unforgiving body against a homogenous and somewhat
15 stiff undersurface; however, their use as a patient support
16 medium is impractical. Then again, if enclosed in a container
17 of soft tough and highly flexible material, air is much more
18 suitable for patient support if designed correctly to reduce
19 hammocking.

20 Consequently, by using air in tubular or oval containers
21 and arranging appropriately within the bed frame, a mattress
22 of air tubes is a reasonable approach, depending on cross
23 sectional area of bladders and their positioning. Shaping
24 these air tubes and putting holes in them to circumvent
25 accidental needle punctures and with a pump sufficiently
26 large to keep ahead of the leak rate, had its merits.

1 Although Armstrong, US Patent 2,998,817, first developed
2 an inflatable massaging and "cooling" system, as time passed,
3 materials were developed that had built in leak rates
4 suitable for beds and thus the current Low-Air Loss mattress
5 approach evolved using so-called vapor-permeable materials.
6 Such materials may consist of 80 denier nylon, or
7 thereabouts, backed with a material of choice such as a film
8 of urethane or vinyl.

9 Hess, US Patent 4,638,519, demonstrated use of shaped
10 bladders using such materials with appropriate individual
11 bladder control and methods of bladder attachments with air
12 supplies while Goode, US Patent 4,797,962, used the process
13 of controlling these air bladders in groups as a means of
14 modifying support pressure under portions of the body as
15 others have done in the aforementioned. (Some of these
16 approaches have been prone to collapse when the patient is in
17 the sitting position in the bed, consequently exposing the
18 coccyx and ischial tuberosities [sit bones] to excess
19 pressure and shear due to increased bladder loading by the
20 vertical component of the trunk.)

21 Some have attempted to reach suitable body support through
22 the use of foam on top of slats placed on top of air
23 cylinders as outlined by Wilkinson, in US Patent 5,070,560.

24 High Density Fluid. Reswick, in US Patent 3,803,647,
25 used a mixture of Barium sulfate ore and water (or other
26 fluids) as a medium of support with a loose fitting lifting
27 interface sheet as the top member of the unit. This sheet was

1 inflated and allowed access to the patient at a suitable
2 working height for the attendant personnel. The aqueous
3 solution of barites was used as its specific gravity could be
4 much greater than "1" and thus support a body without
5 immersion problems of water only. This specific gravity,
6 greater than "1", allowed the patient to lay in the solution
7 and be supported up the body sides to an optimum immersion
8 point. If the specific gravity is too high, excess pressures
9 can be exhibited as area of support is drastically reduced.
10 Keeping the mixture sufficiently fluidic presented a
11 maintenance problem that led to patent disuse.

12 This patent also addressed shaping of the container to
13 reduce the contained mixture volume and of a tubular top
14 bladder as a stiffening method of the upper surface of
15 contained fluid for easier patient transfer or performing
16 dressing changes.

17 Thompson, US Patent # 4,357,722, demonstrates a flexible
18 open mesh approach in a special bed frame to support the
19 patient interfacing medium to change tension of support under
20 various portions of the body.

21 Hargest et al, US Patents 3,428,973 and 3,866,606, used
22 fluidized beads to create a specific gravity greater than "1".
23 These beads were micro-balloons approximating 100 microns in
24 diameter and were "fluidized" by an air plenum chamber placed
25 at the base of the beads separated by appropriate filtering
26 and restrained to remain adjacent to the patient by another
27 optional filter. Fluidization depends on the pressure drop

1 across the supporting beads and that of the filtering system.
2 Excess drop reduces fluidization, increases heat loss and can
3 create ballooning of upper cover. It is thus necessary to
4 adjust pump flow to match patient needs and size.

5 Lacoste, US Patent 4,481,686 controls bacteria through
6 bead selection.

7 Goodwin addresses support of beads in his US Patents
8 4,564,965, 4,672,699 and 4,776,050 with sequential diffusion
9 of beads in 4,637,083.

10 Viard in US Patent 5,402,542 demonstrates use of a
11 programmable EPROM and heat exchanger to control bead system
12 component temperatures.

13 River sand has also been used in place of beads and
14 periodically "fluidized" with marginal success.

15 Yet another approach that may be considered somewhat fluidic
16 is the use of gel and air wherein a semi fluid gel is used in
17 place of the fluidic bead systems in much thinner beds than
18 the units discussed above. Due to the nature of the gel,
19 however, its accommodation of high forces is somewhat
20 limited.

21 2. Use of polymeric foam such as polyurethane

22 Flat Stock. Polyurethane is formed through the mixing of
23 different polymers under controlled conditions. Some
24 manufacturers provide the fabricator with huge blocks of foam
25 which are then cut into required sizes and sold to various
26 fabricators of furniture, mattresses and so on. Some of this
27 stock is sold as is or as a finished item when placed within

1 some acceptable cover consistent with industry requirements.
2 Some foam is rigid and some flexible.

3 As can be readily acknowledged, flexible foam acts
4 somewhat like a spring. It is well known that the further a
5 spring is compressed the stronger is the resisting force of
6 that spring, and so it is with foam. The unfortunate part of
7 this foam as a support media is that our bodies are not flat
8 and our hips protrude further than our waist. Accordingly,
9 when one is sidelying on foam, the hip sees more "spring-back"
10 (foam fightback) or a higher load than our waist. This hip
11 bone (Trochanter) is poorly vascularized and thus the tissue
12 at its surface can be robbed of the desired blood to keep the
13 tissue healthy. Thus the enervated person is unaware of the
14 damage being incurred with this load, the tissue dies, and the
15 result is a "sore" where the skin integrity is forever damaged
16 without surgical intervention. Other parts of our bodies such
17 as the heels, malleolus (ankles), iliac crest (pelvis), coccyx
18 (tailbone), ischial tuberosities (sit bones), scapula
19 (shoulder blades), occiput (back of head), elbows and ears are
20 areas that are also poorly vascularized and prone to breakdown
21 with small loading of tissue in these areas.

22 Those with normal sensation and mobility feel this excess
23 tissue load as a discomfort and move away, thereby restoring
24 circulation in the region. It has been clinically noted that a
25 sleeping person will normally move more than twenty times
26 during an eight hour period on a "so called", standard
27 mattress.

1 Thus flat stock foam, using current technology, is not
2 very desirable for patients at-risk of tissue breakdown or for
3 their comfort. Some materials tend to give way with applied
4 load as in the case of materials used for the Apollo astronaut
5 couches, however, this material known as "visco-elastic foam,
6 is expensive, is temperature sensitive, heavy, flaky, tends to
7 tear readily, and has not been generally used by the bedding
8 industry in the past.

9 Flexible polyurethane foam has been the material of choice
10 most recently. These materials are available in many densities
11 and Indention Force Deflections (IFD). Densities may range
12 from the soft 1.1 pounds /cubic foot up to about 7 pounds
13 /cubic foot and an IFD range of about 14 to 180 is commonly
14 used for bed support purposes. These foams are generally
15 manufactured as a polyether, polyester, high resiliency or
16 other, foam, with all exhibiting different characteristics.
17 The polyether materials are generally found in furniture while
18 the polyester is used in packaging requiring fire resistance
19 while high resiliency may be found where continual cycling is
20 encountered. Other foams also include rubber and other
21 compounding which have not found great favor in the
22 bedding/cushioning industry.

23 Although combinations of many of these foams is common
24 knowledge in the industry, polyether material is less
25 expensive and it may be found in products where replacement is
26 no problem or where material is not used extensively. Its

1 durability under continual loading has generally been less
2 than desirable.

3 Cut or Shaped Foam Stock. Reducing forces encountered in
4 flat stock of polyurethane was obtained through reduction of a
5 foam support in the bony areas by cutting the foam in a
6 special pattern as proposed by Rogers (the inventor herein) in
7 US Patents 3,885,257, 3,866,252 and 4,042,987. Others also cut
8 foam as disclosed in US Patents 3,828,378 by Flam, 4,901,387,
9 by Luke and later 5,025,519 and 5,252,278 by Span. Kraft in
10 US Patent 4,679,266 simulated foam support by zones of inner
11 (mattress) springs with varying strengths.

12 Murphy in US Patent 4,628,557 and Rogers (inventor herein)
13 in 4,042,987 and 4,903,359 could make a selection of foam
14 removal under affected areas of the patient, and in Rogers's
15 case, overloaded adjacent support members rolled automatically
16 into the vacancy to spread load gradually to adjacent areas.
17 Bony areas of the body can be free of all force in foam
18 products through use of material cutouts in mattresses,
19 mattress replacements, body conforming supports, or cushions,
20 but shearing forces at the demarcation edge of support and no
21 support are a harbinger of tissue death unless that
22 demarcation is gradual and can be overcome by the body's
23 internal blood pressure without creating total occlusion of
24 the blood supply. It is then of paramount concern that proper
25 shaping of the edges of regions where foam is removed is built
26 into any design of a support surface so that loading is
27 transferred gradually to adjacent support areas of the body

1 more amenable to the applied forces (putting the load where
2 the body can tolerate it). Some methods to do this are
3 disclosed in US Patents 5,127,119 and 5,048,137 by Rogers
4 (inventor herein). Foam is cut away from bony areas and edge
5 or shear effects are accommodated by cutting foam around the
6 removed foam area to create supporting foam forces "normal" to
7 the body and give a gradual buildup of load over a reasonable
8 area where blood flow is not compromised. One patent discloses
9 technique of load spreading through shaping of the cutout
10 conically or approaching a bell shape.

11 Convolute foam, initially used in anechoic chambers, is
12 formed from flat stock put through a convoluting machine, and
13 has been used as a mattress or pad where patient is supported
14 by a number of peaks and valleys, such as described by
15 Schulper, in US Patent 3,197,357. This machine can produce two
16 products 4" thick from one five inch piece of foam. Obviously
17 material is spread equally between the two halves in such a
18 manner as to create a peak of four inches with valleys to
19 offset the adjacent peaks, a type of "mirror" image.

20 Peak sizes were varied as well as depth of valleys in an
21 attempt to equalize forces without complete relief of affected
22 areas. In some instances manufacturers cut the peaks off some
23 of these convoluted pads in an attempt to control support load
24 distribution. Most of this type material was fabricated from
25 inexpensive foam and has been banned from use in many medical
26 facilities across the USA because of its inability to
27 eliminate damaging forces on body tissue when the user had

1 expected more protection than the material could provide
2 without extensive forming, cutting or modified as proposed in
3 the subject patent.

4

5 SUMMARY OF THE PRIOR ART

6 From the foregoing, it is clear that many different
7 approaches have been used in an attempt to reduce discomfort
8 and injury in a bedridden patient. Such discomfort and
9 possible injury is a direct result of the stress concentration
10 created by the non-uniform shape of the human body. An ideal
11 supporting structure would distribute the forces due to the
12 body weight in a way to minimize or eliminate any localized
13 concentrations of stress, particularly shear, such as would
14 occur at a discontinuity in the underlying material.

15 However, this does not mean that a uniform distribution of
16 stress is the most desirable result. Where bony structure in
17 the body is near the surface and not protected by a reasonable
18 thickness of soft tissue, an effort should be made to greatly
19 reduce or even to eliminate the stress in that region,
20 compensating by slightly higher forces elsewhere, where the
21 body can tolerate it. Total elimination of stress locally is
22 particularly important to promote healing where a bedsore or
23 injury already exists so that the affected site can be readily
24 supplied with a healthy flow of blood. This same thinking is
25 also appropriate for all sites of the body where blood flow
26 may be compromised by an inappropriate body support medium.

1 The prior art has not as a rule directly addressed this
2 goal. Although it has been generally recognized that a
3 support structure for the human body needs to provide
4 different stress patterns in different areas, most schemes do
5 not fully achieve it. In fact, some have discontinuities in
6 material and make no apparent attempt to minimize shear stress
7 at those points.

8

9 BRIEF SUMMARY OF THE INVENTION

10 This invention relates to the support of a person in the
11 prone, supine, sidelying, semi reclined or sitting position
12 without the usual stress concentrations which may lead to
13 tissue trauma, decubitus ulcers or bed sores. It is an object
14 of the present invention to provide support for a human body
15 in a manner so that the forces of support have fewer
16 concentration points which are likely to occur at or near bony
17 prominences, nerves, or tendons, and which, if not
18 accommodated, can lead to serious complications such as bed
19 sores, nerve damage, or strained tendons.

20 This invention addresses the stress distribution problem
21 by combining several techniques. First, using a basic foam
22 inner material, or other that gives a similar performance, the
23 invention provides regions where material has been cut in some
24 selected manner, cut away, omitted, or formed to reduce the
25 magnitude and abruptness of any stress concentrations when
26 supporting a body. This technique is then combined with the
27 process of applying a membrane over the insert material to

1 smooth out the localized variation in stress and
2 concomitantly, if the membrane is able to control the amount
3 of air or fluid surrounding the space between the bladder and
4 interstices of the foam, the fluid pressure may be varied to
5 change the characteristics of the foam itself. This can be
6 characterized by reviewing US patents 5,127,119 and 5,048,137
7 by Rogers and observing that if these patented products were
8 loaded by a body, the foam will "fold" over "normally" to the
9 tissue of the body to reduce the shearing occurring at the
10 tissue. However, if a bladder were to also be placed between
11 the body and the supporting foam discussed, the bladder, with
12 air control ability, can hold the foam in its desired place
13 without the normally concurrent fightback of the foam and thus
14 the "shear" or pressure known to damage the tissue, nerves, and
15 tendons. The body is virtually floated by a high specific
16 gravity through a combination of foam, bladder and fluid
17 pressure. But, the foam or supporting medium must be
18 previously pre-shaped for this system to work as designed.

19 It is this combination of techniques that accomplishes, in
20 a superior way, the desired goal of comfort and safety of the
21 patient. "Comfort" has been shown to be directly related to
22 forces exerted on the body by Rogers in the "Hospital Materiel
23 Management Quarterly" article, "Body Support Testing and Rating"
24 dated August 1992.

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1 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

2 Figure 1 is an embodiment wherein a foam mattress,
3 containing one or more regions where foam has been cut away,
4 is inserted into a closely fitting bladder in which the
5 pressure of a fluid can be controllably varied.

6 Figure 2 depicts the deformation of a foam material around
7 a cylindrical cut-out in the material when an irregular object
8 is placed thereon.

9 Figure 3 shows how the material deforms when an inverted
10 conical hole is in the support material.

11 Figure 4 shows how the material will deform if the cut-out
12 is tapered away from the hole progressively from top to
13 bottom.

14 Figure 5 shows a detail of the deformation around a cut-
15 out placed within a bladder.

16 Figure 6 is a view of an insertable foam pad with undercut
17 edges.

18 Figure 7 depicts an insert containing modules of different
19 types of foam in different areas with undercutting at the
20 joint.

21 Figure 8 shows a modular device with individually
22 pressurized sections.

23 Figure 9 shows a convoluted foam material inserted into a
24 bladder.

25 Figure 10 shows a convoluted pad inserted with smooth side
26 up, containing a cut-out for localized pressure relief.

27

1

2 DETAILED DESCRIPTION OF THE INVENTION

3 The basic features of the invention can be seen in figure

4 1. A foam pad 1 of any size or shape, containing one or more
5 cutouts 2, is inserted into a closely fitting airtight bladder

6 3. A valve 4, is affixed to an opening 5, and an optional
7 pumping means 6, for pressurizing or evacuating the bladder

8 may be attached. It should be noted that the shape of the pad

9 in figure 1 is for demonstration only and that the pad may

10 also be in the shape of a torus, a circle, or a square for

11 example, with a rectangular, or other-shaped center portion

12 removed, or for that matter, any suitable body supporting

13 shape.

14 As demonstrated by Rogers(inventor herein), U.S.Patent

15 #5,048,137, the deformation of a foam mattress around an

16 opening through the foam in the form of a truncated upright

17 cone(small radius at top)or bell-shaped, is such that the

18 material around the edges of the opening tends to "roll" into

19 the cavity when a load is placed upon the portion of the

20 mattress containing the cut-out. The result is that instead

21 of an abrupt change in force distribution at the edge of the

22 cut-out, the distribution changes more gradually at the

23 approach to the opening. This desirable condition comes about

24 because the shape of the cavity is such that there is

25 gradually less and less material as the edge of the opening is

26 approached, hence the spring constant or fight-back is reduced

27 near the cut-out in a manner suitable for gradual force

1 reduction commensurate with blood pressure supply to the
2 supported site.

3 However, the gradual diminishing of the forces on the body
4 as the cut-out is approached only occurs where the material
5 slopes back away from the opening into the foam. If the sides
6 of the opening are vertical, whether a cylindrical,
7 elliptical, or other shape, the body will see a higher stress
8 concentration near the opening. This effect can be seen in
9 figure 2. Since the force on the body is proportional to the
10 amount of compression of the underlying material, when a body
11 of irregular shape as shown, is supported over the opening,
12 the forces will increase near the cut-out, and drop sharply
13 within the opening.

14 On the other hand, as in figure 3, where the top of the
15 opening is larger in cross section than below, the body will
16 see a stress concentration near the edge of the opening, and
17 also at the point where the body loses contact with the
18 underlying material and is unsupported across the opening.
19 But where the opening is undercut as in figure 4, whether the
20 opening is in the form of an inverted cone or of some
21 horizontal cross section other than circular, as the opening
22 is approached there is less material under the body and the
23 forces upon the body will be reduced gradually because the
24 material can bend or "roll" into the opening as shown with a
25 reduced "spring constant" and concomitant force on the
26 supported body.

1 Thus, figures 2,3,and 4 demonstrate how the shape of the
2 cut-out plays a significant role in controlling stress
3 concentrations in supporting a body.

4 Now, when the foam or other material is placed inside a
5 bladder wherein the fluid pressure may be varied, two
6 additional effects are observed. First the membrane of the
7 bladder extends over the opening adds support to the supported
8 body in the form of a "hammocking" effect. The amount of
9 hammocking support will be determined by bladder composition
10 and adds considerably to the smoothing effect, further
11 reducing any abrupt changes of pressure on the body.

12 Another factor arises from the ability to vary the
13 pressure of the fluid inside the bladder. Within the cells of
14 the foam the variation of pressure changes the spring
15 constant of the foam. At the same time, in the cut-out
16 section, the pressure of the fluid directly determines the
17 local force distribution on the supported body. This is shown
18 in more detail in Figure 5 which is a cross section of an
19 undercut cut-out encased in a bladder showing the resulting
20 deformation of the foam.

21 Thus, the invention disclosed herein provides for
22 simultaneously varying both the shape of the supporting
23 material and its resiliency. These variations are
24 accomplished by selectively cutting, removing, omitting or
25 shaping material and by varying the resiliency of the material
26 with fluid pressure in the cells of the material.

1 In one embodiment, the invention is a foam pad shaped as
2 desired for a mattress, pillow, body support device or
3 cushion, which contains one or more cut-outs in preselected
4 locations. These cut-outs will preferably have outwardly
5 sloping sides, being smaller at the top than at the bottom.
6 It is obvious that the amount of force gradation on the
7 supporting body is directly related not only to the type of
8 support material but also the slope and shape of the cutout,
9 the bladder material, and the amount of contained fluid.
10 Therefore, it is possible to tailor the support device to the
11 needs of the body resting thereon.

12 If the edge of the support structure impinges on any
13 portion of the body, such as the heels or the back of the
14 knees when seated, then in order to avoid stress
15 concentration, that edge should be sloping inward from top to
16 bottom as in figure 6. Figure 6 shows the same type of roll-
17 over effect as earlier shown in the cut-outs. The same
18 principle also applies to the inner surfaces of a ring or a
19 so-called doughnut. Otherwise a tourniquet effect will reduce
20 the blood supply in the center and create a blood flow
21 limiting situation and the possibility of tissue death within
22 the ring.

23 The foam insert is placed in a close-fitting bladder or
24 membrane containing a passageway for air or other fluid to
25 enter or leave. A valve or other means for controlling the
26 internal pressure may be fitted to the bladder as was shown in
27 figure 1. This fitting may be connected to a pressure or

1 vacuum pump or simply left open initially and closed when the
2 body is in position upon the mattress, pillow, support module,
3 or cushion. In this latter case the foam fight-back has been
4 reduced over sloping edges making the body support surface
5 free of unwanted shear at the edges. Without the outer
6 membrane and with the surrounding air pressure normal such
7 shear is likely to be encountered.

8 Alternatively, it may be desirable to simply hermetically
9 seal the bladder either by conventional sealing means or by a
10 Ziploc® type closure after establishing the desired internal
11 pressure. On the other hand one might use a semi-permeable
12 membrane or a controllable orifice so that the weight of the
13 body would force the air out slowly, allowing the pad to
14 assume a shape conforming to the body. Of course cut-outs may
15 be placed in appropriate locations to further enhance the
16 patient's comfort and tissue health, however, if cross-
17 contamination or dust mite restriction is part of the patient
18 physical support consideration, appropriate filtering or
19 support personnel regimen must be considered in the overall
20 performance specification of the patient physical support
21 system.

22 Another method of varying the resiliency of the support is
23 to cut a number of slits in the material as was shown by Flam,
24 U.S. Patent 3,828,378. The placement of these slits will
25 result in varying compressibility or resiliency. By combining
26 this technique with the pressure variation in the bladder and
27 optional cut-outs, a much wider range of controllable

1 properties can be obtained. The foam, where slit will act
2 like a collection of individual springs, much as in an
3 innerspring mattress. It will also be possible to vary the
4 spring effect in different areas of the mattress and then
5 provide the bedridden person with even greater degree of
6 comfort by changing the pressure in the mattress and/or adding
7 shaped cut-outs.

8 Another means of providing variable force distribution is
9 to use different types of foam in different areas as shown in
10 figure 7. This would not be limited to any particular shape
11 of the foam. For example, one could fill in one or more of
12 the cut-outs with a softer foam plug to get even more
13 variation in the local resiliency. Lateral strips of foam may
14 be used and the different effects of the pressure variation in
15 the different foams would allow a seemingly endless variety,
16 especially if combined by the ability to vary fight-back of
17 the supporting material by varying pressure. Cross-
18 contamination between patients can be readily controlled as
19 can dust mite invasion into the inner core of the unit.

20 A further refinement on using different foams is shown in
21 Figure 8. In this embodiment, each section is encased in an
22 individual bladder wherein the pressure can be maintained
23 independently of the others. It should be noted that the
24 principles of undercutting have been carried over from the
25 earlier embodiments, as shown in figure 8, in order to
26 minimize stress peaks arising from discontinuities at the
27 joining of different foams. Where there are joints between

1 two types of foam, whether or not they are in independent
2 bladders of the type shown in figure 8, the firmer material
3 should extend over the softer one as shown in figures 7 and 8.
4 The outer cover itself may be sloped to match the material
5 within and assure that gradation support transfer is
6 acceptable to tissue restraints.

7 Finally, figures 9 and 10 show two different techniques
8 for using a convoluted foam material within the bladder. In
9 figure 9 the material is inserted with the convolutions
10 upward. In this configuration, the use of cut-outs is of less
11 obvious value, although they would still provide some pressure
12 relief in the areas where no material is left. Figure 10
13 shows the use of the convoluted material in an inverted
14 position, where the cut-outs would be of more value in
15 reducing pressure concentrations.

16 The numerous embodiments covered herein are by no means
17 exhaustive. Some variation suggested by the foregoing
18 techniques will no doubt occur to those skilled in the art,
19 and the application of the above principles would follow
20 directly.

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